M. Technical Cost Modeling

Principal Investigator: Sujit Das
National Transportation Research Center
2360 Cherahala Boulevard
Knoxville, TN 37932-6472
(865) 946-1222; fax: (865) 946-1314; e-mail: dass@ornl.gov

Technology Area Development Manager: Joseph A. Carpenter
(202) 586-1022; fax: (202) 586-1600; e-mail: joseph.carpenter@ee.doe.gov
Field Technical Manager: Philip S. Sklad
(865) 574-5069; fax: (865) 576-4963; e-mail: skladps@ornl.gov

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Objectives

- Address the economic viability of new and existing lightweight materials technologies.
- Develop technical cost models to estimate the cost of lightweight materials technologies.

Approach

- Address the economic viability of lightweight materials technologies supported by ALM Technology Area Development.
- Use cost modeling to estimate specific technology improvements and major cost drivers that are detrimental to the economic viability of these new technologies.
- Derive cost estimates based on a fair representation of the technical and economic parameters of each process step.
- Provide technical cost models and/or evaluations of the "realism" of cost projections of lightweight materials projects under consideration for ALM Technology Area Development funding.
- Examine technical cost models of lightweight materials technologies that include (but are not limited to) aluminum sheet; carbon fiber precursor and precursor processing methods; fiber-reinforced polymer composites; and methods of producing primary aluminum, magnesium, and titanium and magnesium alloys with adequate high-temperature properties for powertrain applications.

Accomplishments

- Assessed cost of primary magnesium production for automotive applications.
- Compared life-cycle energy impacts of automotive liftgate inner.
- Assessed comparative cost of alternative manufacturing technologies for the composite-intensive body-in-white (BIW) structures.
- Initiated a new task looking at the lightweighting opportunities for fuel cell vehicles.

Future Direction

- Estimate the lightweighting opportunity toward the early commercialization of fuel cell vehicles.
- Estimate the impacts of the Phase II ALM Technology Area Development for the 2000–2005 period and also aid in the formulation of midterm and long-term goals for the FreedomCAR Program.
- Continue to explore the economic viability of a carbon-fiber composite, intensive BIW part for Focal Project 3 by examining alternative competing manufacturing technologies by specific part type.
- Continue individual project-level cost modeling to identify specific technology improvements and major cost drivers that are detrimental to the economic viability of these technologies.

Cost Assessment of Primary Magnesium Production Technologies

Magnesium use in automobiles has been very limited and occurs mainly in die cast structural products. Even with magnesium's significant lightweighting potential, its cost remains one of the major obstacles in its widespread automotive use. The material cost is one of the key cost components, particularly important at high-production volumes. Primary magnesium currently costs about 1.8 times as much as aluminum, and there have been price swings during the past decade due to supply and demand imbalances. It is important that the competitive magnesium price for the substitution of materials such as aluminum and steel in automotive applications be estimated based on the material density as well as performance. While maintaining the design at equal stiffness, magnesium has maximum weight reduction potentials as high as 62% and 41% for the substitution of steel and aluminum, respectively. Compared to the 2001 magnesium price of \$1.25/lb, the competitive magnesium price is estimated to be in the range of \$0.78–\$1.19/lb for a substitution of existing automotive aluminum components. Current and future production cost estimates (which include both full operating and capital costs) of magnesium were examined to determine the viability of existing production technologies for magnesium's commercial viability as a promising automotive material.

Although the full operating cost of primary magnesium is estimated to be cheaper using electrolytic plants than thermal reduction plants, total production cost is higher for electrolytic plants due to the capital-intensive nature of the process. The current production costs are estimated to be \$1.41/lb and \$1.31/lb, respectively. With planned electrolytic production capacity increases involving new plants and existing-plant capacity expansions, a substantial decline in the primary magnesium production cost is projected for the year 2009. For electrolytic and thermal reduction plants, the costs in 2009 are projected to be \$1.14/lb and \$1.27/lb. With these production cost projections and the existing depressed aluminum prices, magnesium will be competitive with aluminum only when the maximum weight reduction potential (i.e., about 40%) is possible in niche automotive applications. A further reduction in primary magnesium production cost may be necessary if aluminum prices do not recover in the future and for applications where this high rate of weight reduction may not be attainable either due to part design and/or manufacturing technology limitations. These production cost estimates further indicate that the average market price of magnesium in recent years has barely recovered its production cost from the depressed market. The industry may be profitable with the significant, future reductions in projected production costs, strong demand, and consistent supply that precludes price swings observed during the past decade.

Life-Cycle Energy Impacts of Automotive Liftgate Inner

The life-cycle energy comparisons of cast aluminum vs conventional stamped steel liftgate inner used in a DaimlerChrysler minivan were completed. The low-pressure, permanent mold casting process with significantly low tooling cost developed for ultra large automotive components under the recently completed DOE project is used for the cast aluminum part. Using the best available aggregate life-cycle inventory data and a simple spreadsheet level of analysis, energy comparisons were made at both the single vehicle and fleet levels. Analyses were also done to examine how sensitive is the level of analysis (single product vs fleet level) and the assumptions behind each of the major baseline data to determine the most favorable materials with respect to life-cycle energy benefits.

As expected, life-cycle energy impacts of aluminum are lower than steel at a product level—energy savings are estimated to be 1.8 GJ/vehicle (or 1.7 million Btu) as shown in Figure 1. Assuming 10% and 20% penetration rates of this technology in the projected light-duty vehicles of sales of 18.27M and 19.91M by 2010 and 2020, respectively, by the Energy Information Administration, DOE, energy benefits for those years are estimated to be 3289 TJ (3.1 trillion Btu) and 7168 TJ (or 6.8 trillion Btu), respectively. The estimated energy benefits represent only a small fraction of total light-duty vehicles energy use of 17×10^{18} J (16.1×10^{15} Btu) in 2000. In addition to lower estimated energy savings, savings are achievable only after vehicles are retired and recycled. Most energy savings occur at the vehicle operation phase due to improved fuel economy from lightweighting, but the savings are not large

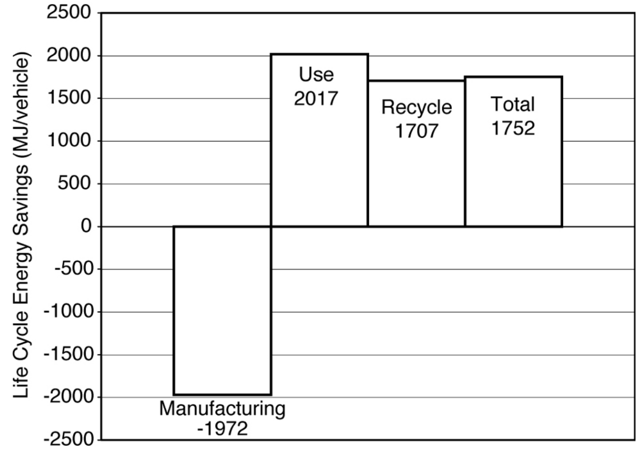

Figure 1. Life-Cycle Energy Savings of Cast Aluminum Liftgate Inner.

enough to annul the effects of high manufacturing energy use. In the first generation, the energy benefits are realized only after 13 years of vehicle operation (close to the standard 14-year vehicle life assumed in the analysis). At the vehicle fleet level with a flat growth rate, it takes longer—about 21 years—for aluminum to achieve life-cycle equivalence with steel.

As with any analysis, results in this study are sensitive to the assumptions made, particularly those regarding the aluminum substitution factor, manufacturing energy, aluminum recycling, and operational fuel efficiency. The number of years aluminum needs to achieve equivalence with steel is quite sensitive to aluminum manufacturing energy and fuel economy. A 25% decrease in aluminum manufacturing energy, which could result from changed assumptions regarding the manufacturing process efficiency and/or recycled content, will change the point at which aluminum achieves life-cycle equivalence with steel by about 6 and 7 years at the vehicle and fleet level, respectively. A 0.30% improvement in fuel economy (compared to 0.20% improvement under the base case), resulting from different fuel efficiency improvement factors due to vehicle weight reduction and/or secondary weight savings, would significantly lower the number from 13 years to 6 years when the benefits can be realized at the vehicle level.

The energy benefits increase significantly with a higher weight reduction potential of cast aluminum liftgate inner (i.e., 35% instead of 21% under the base case), the life-cycle equivalence point at the vehicle level reduces from 13 years to 4 years. The effect of an improvement in the aluminum recycling efficiency is felt only at the vehicle fleet level, by achieving the life equivalence point 2 years earlier than under the base case. Due to relatively low manufacturing energy of steel, results of the sensitivity analysis were not that significant. Because energy benefits at the vehicle fleet level take significantly higher number of years, any parameter that increases the energy usage raises further questions to the viability of aluminum substitution from an energy perspective.

As the race toward the lightweighting by the steel industry continues, a systems approach, instead of part-to-part comparison, is more appropriate in the determination of viability of aluminum substitution from an energy perspective. The extent of light-weighting that aluminum can provide with improved vehicle designs and increasing the recycled content of aluminum will be critical determiners of aluminum's life-cycle benefits. Lastly, a fleet level analysis is appropriate to provide a better indication of the relative environmental merits of alternative products designs and helps in the prediction of time when benefits are realized.

Comparative Cost Assessment of Alternative Carbon-Fiber-Reinforced Composite BIW Manufacturing Technologies

This task continues to focus on the relative cost-effectiveness of competing carbon-fiber-reinforced, polymer composite, BIW manufacturing technologies. The part under consideration is an upper dash panel weighing about 1.9 kg. Of a total of six competing manufacturing technologies under consideration, three are based on the compression molding and long fiber injection processes. The latter process is currently being used by Bayer AG, Dow Chemical Company, and Huntsman. Two carbon-fiber sheet molding compound (SMC) materials for the compression molding process considered are Quantum composites and HexMC by Hexcel Corporation. The former carbon-fiber, sheet molding, SMC material has recently been used in Dodge Viper for the windshield surround, inner door panels, and fender support system applications. Of the three remaining manufacturing technologies, fabric preforms and prepregs besides the programmable powder perform (P4)/structural reaction injection molding process are being considered.

Lightweighting Opportunities for Fuel Cell Vehicles

This ongoing task was initiated to examine the lightweighting opportunities for midsize passenger, direct hydrogen, fuel cell vehicles and to consider whether this would facilitate the early commercialization of fuel cell vehicles. This task will focus on the lightweighting of body structures of a midsize vehicle. Because weight and cost implications are significant not only at this component level but also at the powertrain level and, subsequently, the vehicle level as well, the vehicle level is considered here for the analysis. The current fuel cell powertrain is heavy and expensive, so it is interesting to examine whether at the expense of lightweight BIW materials alone, the fuel cell vehicle penetration rate can be enhanced. The commercial viability of fuel cell vehicles is examined in the context of several advanced lightweight BIW material options alone, as well as in combination with improvements in the fuel cell powertrain. A detailed 35+ vehicle components level automotive system cost model is being used to estimate the lightweighting opportunities for fuel cell vehicles.